

Influence of forage crop rotations on crop yields and phytosanitary conditions of soils in the Baikal region

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Abstract. The article considers the practical aspects of ensuring the preservation of natural ecosystems based on the use of organic farming technologies. It presents the results of research in the forest-steppe zone of the Baikal region for 2011-2018. On the basis of the phytosanitary state of crops studying analysis, it was found that the correct alternation of crops in crop rotation suppresses the level of weeds, thereby not affecting the productivity of agricultural crops. The paper reveals the characteristics of agrophysical and water properties of gray forest soil, the influence of forage crop rotations with meadow clover on the yield of cultivated crops. According to the research results, the authors found that overseeding of legumes in the fields of forage crop rotations increases the average productivity by 16.6% in comparison with the control option. The influence of the aftereffect of perennial legumes in crop rotations increases the yield of grain fodder and silage crops by 20-31.8%. The crop rotation with two fields of meadow clover (crop rotation No. 3) was determined to be the best for all indicators.

1 Introduction

Issues related to ensuring society sustainable development are gaining priority, becoming a central task in managing both the country and the region, as well as an organization itself. The solution of this problem should be of great importance for agricultural enterprises, taking into account the biologization and greening of the applied technologies. The achievement of the Sustainable Development Goals proclaimed by the United Nations largely depends on the performance of this sector [1]. In particular, this applies to such goals as:

- Eliminating starvation, ensuring food security and improving nutrition, promoting sustainable agricultural development.
- Ensuring the transition to sustainable consumption and production patterns.

On the first goal, the UN Report notes that approximately 75 % of crop species have been lost in cropping patterns over the past 100 years, which requires better management of

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agricultural biodiversity, which can contribute to improving nutritional value and efficiency of agricultural systems.

On the second goal, the UN Report notes that land degradation and soil fertility decline the ability of natural resources to provide food. As a result, objectives are set for the rational use and reduction of chemicals and wastes in accordance with the adopted rules.

In every country of the world, concepts and programs for ecosystem growth and conservation are being developed, supported by a number of legislative and regulatory acts aiming to implement these programs. In Russia, at the national level, in the Federal Program for the Development of Agriculture [2], the goal is to ensure a stable growth in agricultural production obtained by using the seeds of new domestic varieties and breeding products, technologies for the production of high-quality feed, feed additives for animals and other aspects. Taking into account the above, the Program sets goals and proposes a mechanism for implementing measures to ensure sustainable development of the country in the field of agriculture.

Through considering global and national goals and objectives in the sphere of sustainable development of natural ecosystems for domestic crop production, it can be formulated that the development of soil protection methods, increasing yields and labor productivity in all regions of the country should be the most important area of modern agriculture. For this, in each region, taking into account the peculiarities of natural and climatic conditions, local programming should be started to solve the problems of achieving and maintaining sustainable and effective development of agriculture in the region.

Thus, in the documents of Irkutsk region [3, 4] it is told about the potential and strategic importance of agriculture for sustainable development of the region, about the ways to improve the farming system based on the development of such areas as biologization and greening. In this regard, the tasks are set for the progress of scientific and practical methods of organic farming and crop rotation. Moreover, in crop rotations, the saturation with perennial leguminous grasses, which play an environment-forming role, should be 20-40 %.

Meanwhile, a problem in the region exists that has formed due to a change in the structure of cultivated areas, in which there was an increase in the share of cereals and a decrease in the share of legumes. This led to a violation of the rules of fruit change in the farming system and crop rotations of the region, which affected the level of soil fertility, productivity and quality of food and forage crops. Years of research (1977-2015) showed that the area of arable land with low and very low humus content increased from 624.2 thousand hectares (36.4 %) to 727.7 thousand hectares (43.9 %) [5], which leads to insufficiency in providing the population with food, and animal husbandry - with fodder.

The solution of this problem seems to be an urgent task, which served as the basis for choosing a research topic aimed to develop specialized fruit-changing forage crop rotations, including in their structure perennial legumes, which play the role of green manure and phyto-meliorative plants in crop rotations.

Meanwhile, long-term studies concerning the assessment of the bioecological, agricultural and economic efficiency of specialized forage crop rotations with green manure and phytomelioration in the region remain insufficient.

The essence of the research is to consider, on the one hand, the influence of forage crop rotations on the degree of fields phytosanitary and the yield of forage crops as the most important indicators of agriculture; on the other hand, the influence of these indicators on the achievement of objectives set in federal and regional programs of the Irkutsk region natural resources development.

Under the current conditions, crop rotation is the most affordable and effective means of using soil nutrients, which helps to improve and maintain its favorable physical and biological properties. The study of various types of forage crop rotations allows to conclude

that it is possible to stabilize soil fertility and increase the productivity of crop rotations by sowing perennial and annual legumes, overseeding the legume component, etc. [6].

Researchers [7], based on their experience, rely on mixtures of legumes and herbs in their crop rotation as a source of organic nitrogen, since legumes can fix atmospheric nitrogen, which is the most important element for plant growth.

Other scientists [8] recommend the following measures: firstly, focusing on proven farming practices, including crop rotation and forage crops, and secondly, supporting production of forage crops that have a positive effect on soil fertility and animal husbandry development.

The purpose of the research is to assess the phytosanitary state, productivity of forage crop rotations and their impact on the main indicators of soil fertility to obtain environmentally friendly livestock products.

Research objectives:

- Tracing the dynamics of crops weediness in forage crop rotations.
- Analyzing productivity of forage crop rotations with perennial crops having different use duration.
- Determining the effect of forage crop rotations with perennial legumes on the state of gray forest soils.

2 Research methods and stages

To determine the most promising areas for the development of agriculture and crop rotations in the region, scientific and statistical data on the problems of agriculture in the Baikal region associated with fodder production and food supply were studied.

Research was carried out in 2011-2018 on the experimental plots of Irkutsk Research Institute of Agriculture. To reach the research objectives, a field experiment was laid with fodder five-field specialized crop rotations.

Research stages:

At the first stage of research in 2011-2012, the establishment of three five-field forage crop rotations was carried out with different saturation of the alternation patterns with fields of perennial legumes (meadow clover).

At the second stage, in the period from 2012 to 2018, a study was carried out, according to the results of which it was determined that the inclusion of perennial legumes in forage crop rotations (cover and uncover crops) ensures the sustainable functioning of agroecosystems, increases soil fertility and the productivity of other crops due to activation of biological processes and labile organic substances.

3 Research results

At the initial stage of crop rotations development, the amount of the weed component was not observed. Mechanical treatments have destroyed 75 % of perennial weeds. The species of annual weedy plants are mainly represented by gray mice and wild radish, of perennials – by yellow sow thistle and field horsetail. With a dense, high-yielding herbage of agricultural crops, weed vegetation is oppressed and suppressed by cultivated plants, without exerting a strong effect on crop productivity. The maximum amount of weeds was observed in the crop rotation without clover 13-16.3 pcs/m². The smallest amount of soil weeds was in the crops of oats and meadow clover in crop rotations with two fields of clover.

In 2012, weediness of crops in a crop rotation without perennial legumes before harvesting was: annuals – 32 pcs/m², perennials – 35 pcs/m².

In 2013, a high weediness was shown by the control crop rotation. The largest number of perennial weeds was in corn crops, the smallest was noted in pea and oat crops. On corn crops, when it is not possible to cope with perennial weeds by mechanical means, the herbicide Dublon Gold is used at a dose of 50-70 g/ha.

When placing corn on the clover layer, the number of annual weeds has decreased to 10 pcs / m², and perennials - up to 3 pieces / m². The lowest weediness of crops was noted in crop rotations with meadow clover fields. It happens because dense herbage of clover effects suppressing the weed component.

Dense herbage of meadow clover suppresses most weeds. However, in 2018 after an unfavorable wintering of meadow clover, its herbage appeared sparse in places. This was the reason due to which crop rotations with meadow clover turned out to be slightly weedier than crop rotations without the introduction of meadow clover.

Thus, in order to obtain good productivity in fodder crop rotations and to reduce the level of weed infestation, intensive tillage is carried out, applied before and after meadow clover harvesting. Before sowing agricultural crops, harrowing, cultivation and compulsory soil rolling were carried out. After sowing, the agrotechnical method of rolling the soil was repeated again to improve the contact of seeds and soil interaction and provide their rapid germination.

On average, over 8 years of research, the largest amount of the weed component was found in the crop rotation without perennial legumes, in corn crops 12 pcs/m² and pea-oats crops 12-13 pcs/m² (Fig. 1).

The phytosanitary state in the fields of barley with over-sowing of meadow clover in crop rotations with leguminous had the weediness of 4-7 pcs/m². The lowest weediness of crops, on average, was noted in crop rotations involving meadow clover links 7-8 pcs/m². A slight increase in the number of weeds is associated with shedding of weed seeds by the time of harvesting.

In the fight against weeds, an important role is played by the selection of such an alternation of crops, which suppresses the development of weeds and does not bring their number to economic thresholds of harmfulness.

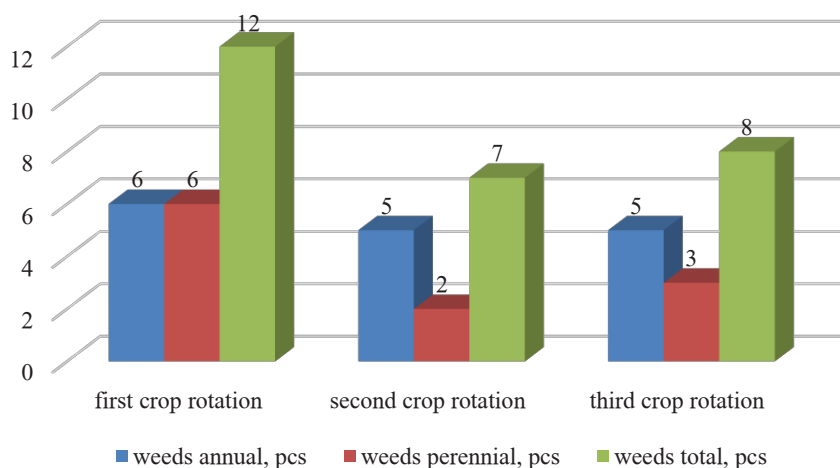


Fig. 1. Effect of 20-40 % saturation of crop rotations with meadow clover on weediness of crop rotations before harvesting, pcs/1 m² (average for 2011-2018).

Analyzing the data obtained, it can be concluded that the weediness of crops did not have a significant effect on decreasing forage crops yield in the links of crop rotation. It is explained by correct alternation of crops in crop rotations.

Table 1 shows the results of studying the effect of specialized forage crop rotations on the state of gray forest soil in the Baikal region.

Table 1. Properties of gray forest soil under the influence of forage crop rotations.

Sampling depth, cm	Soil density, g/cm ³	Specific gravity, g/cm ²	Total porosity, %	The lowest field moisture capacity, mm	Wilting moisture, mm
0-10	1,14	2,62	56,0	32,4	11,0
10-20	1,36	2,62	48,0	31,8	11,9
20-30	1,34	2,62	49,0	30,2	12,6
30-40	1,24	2,68	54,0	30,4	11,3
40-50	1,38	2,75	50,0	25,7	8,2
50-60	1,44	2,76	48,0	23,8	9,2
60-70	1,54	2,74	44,0	22,2	8,4
70-80	1,49	2,75	45,0	21,0	9,4
80-90	1,59	2,78	43,0	22,2	10,0
90-100	1,48	2,77	47,0	24,8	9,7

Based on these data, it can be concluded that the agrophysical and water properties of the gray forest soils have a beneficial effect on the productivity of crops in fodder crop rotations.

Table 2 presents the data characterizing the effect of perennial legumes with different proportions of saturation in crop rotations (one and two fields) on the productivity of fodder crop rotations.

Table 2. Influence of meadow clover on the productivity of forage crops in crop rotations, (average for 2011-2018).

Crop rotations	Fodder units harvest t/ha	Exchange energy, GJ	Digestible protein harvest t/ha
Barley (forage)	1,6	14,8	0,15
Corn for silage	2,2	33,7	0,17
Peas + oats (green mass)	1,8	22,6	0,21
Oats (forage)	1,9	21,8	0,18
Peas + oats (grain)	1,9	20,5	0,21
Average	1,8	22,6	0,18
Barley with clover overseeding	1,7	18,4	0,16
Clover	1,5	16,8	0,18
Corn for silage	2,5	38,3	0,20
Oats (forage)	2,2	25,1	0,21
Peas + oats (grain)	2,1	22,5	0,23
Average	2,0	24,2	0,20
Barley with clover overseeding	2,2	23,0	0,20
Clover	1,5	17,4	0,19
Peas + oats + clover (green mass)	2,1	21,8	0,25
Clover	1,6	18,2	0,20
Corn for silage	2,9	42,5	0,21
Average	2,1	24,5	0,21

On average, under crops of the first crop rotation (excluding meadow clover) productivity was 1.8 t/ha of standard units, which is 11.1-16.6 % lower than in crop rotations with alternating fields of meadow clover. A good indicator of productivity was obtained for crops sown for silage: for corn 2.2 t/ha of standard units (first crop rotation), 2.5-2.9 t/ha in crop rotations with meadow clover, in the crop rotation link peas + oats with over-sowing of the legume component, the yield was 2.1 t/ha. Weather conditions are also considered one of the positive factors affecting the growth of yields. Thus, for the entire period of research, only 2013 turned out to be arid year with only 190.5 mm of atmospheric precipitation.

Overseeding of the legume component in fodder crop rotations contributed on average to an increase in productivity of the entire crop rotation, which makes it possible to obtain a stable fodder base for animal husbandry and improve forage crops quality, due to the powerful effect of legumes on soil environment reaction.

The content of digestible protein in 1 fodder unit in crop rotations on average increased from 90.3 g to 98.1 g (Fig. 2).

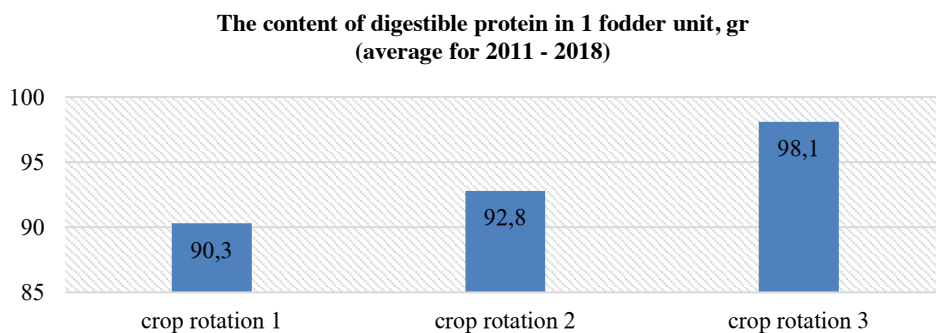


Fig. 2. The content of digestible protein in 1 fodder unit, gr.

Thus, on average within eight years of conducting fodder crop rotations, the most productive is 2.1 t/ha crop rotation with meadow clover overseeding, which uses soil natural organic matter more effectively. This crop rotation turned out to be the best in other indicators (metabolic energy, digestible protein content). Of great importance in increasing the main indicators of crop rotations productivity was the reception of plowing the second field of meadow clover for green manure.

4 Conclusions

When analyzing the results of researching these experiments, the following conclusions were made that are suitable for identifying promising scientific research and making solutions in specific production situations.

1) The developed scheme for introducing links of the legume component into fodder crop rotations provides suppressing and weakening of the growth of various types of weeds, thereby enriching, due to its nitrogen-fixing ability, the fertile soil layer with free organic substances.

2) Plowing meadow clover improved the phytosanitary state of crops. The biological potential of meadow clover in the links of fodder crop rotations contributed to an increase in the average productivity of crop rotations and had a beneficial effect on the fertility of gray forest soil.

3) The incorporation of green mass of meadow clover as a precursor for forage crops creates a looser soil composition within the growing season.

4) Agrophytocenoses with meadow clover sowing on gray forest soils provide an exchange energy of 24.2-24.5 GJ per hectare, 0.20-0.21 tons of digestible protein, 2.0-2.1 thousand fodder units.

Practical application of the obtained research results will allow:

- providing, in comparison with the achieved level, higher productivity of agricultural crops, quality of crop production, environmental safety of agricultural production;
- eliminating soil toxicity through the use of meadow clover biologization in fodder crop rotations;
- reducing and restoring the rate of soil degradation through the use of green manure techniques for perennial legumes.

Crop productivity as an indicator of forage crop rotations developed schemes effectiveness when used by enterprises of the agro-industrial sector will depend on the following factors:

- scientifically based composition and rotation of crops, applied in crop rotations;
- meteorological conditions during sowing, growth and harvesting of agricultural crops;
- composition and structure of the soil;
- technologies, techniques and agricultural methods used during cultivation, harvesting and storage of agricultural crops;
- expansion of perennial legumes cultivated areas;
- constant monitoring of intermediate and final results of crop rotations effect on improving the crop structure;
- qualifications and experience of agro-industrial complex personnel.

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